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Analysis of and Study on the Difficulties in the Fire Protection Design of Large Commercial Complex

MA Qian-li[a,b], HUANG Ting-lin[a,*]

[a]*Environmental and Municipal college, Xi'an University of Architecture And Technology， Xi'an 710055, China*
[b]*Tianjin General Fire Brigade，Tianjin 300090, China*

Abstract

Fire properties of the large commercial complex has been summarized. Based on the fact that there are contradictions between what is required for the large commercial complex in the fire code and the real application in practice, difficulties in fire protection of designing large commercial complex have been analyzed.

Key words: large commercial complex; fire protection design; difficulty; research status

1. Introduction

In recent years, more and more large commercial complexes have appeared in China. These complexes integrate different businesses into on large building, where customers can do shopping, eat or enjoy themselves. According to the statistics, nearly 200 large complexes in China now have indoor walking street, with different kinds of shops standing along both sides. And what's more, the indoor walking street shares the large space with the atrium.

Generally speaking, the large commercial complex is multi-functional with high fire load and large assembly of people. The mechanism of the occurrence of fire is different from that of the ordinary buildings and the fire loss is also heavier. As a result, this kind of commercial complex needs higher fire safety. However, the current national fire code only gives the minimum requirements. No specific fire safety objectives are provided. Therefore, it is quite important to understand the design and research status of the large commercial complex and to provide safe, reasonable and economical fire design method.

2. Characteristics of large commercial complex fire

2.1 High fire occurrence

* Corresponding author. Tel.:+86-22-23387424.
E-mail address: maqianli@tfri.com.cn.

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There are heavy fire loads inside the large commercial complex, which include merchandises like clothes, shoes, hats and combustible decorations. It is widely recognized that electricity is the important factor to cause fire hazard. Therefore, to provide electricity among these combustibles is very dangerous. However, in the large commercial complex, electric systems and equipment are installed to provide electricity for lighting, ventilating and air conditioning. If there is short circuit, spark, poor contact or long time electrifying of the lights or electric heater, fire may be caused. In addition, other factors like improper welding, lighted cigarette ends or arson can cause fire too.

2.2 Quick spread of fire and smoke

If fire occurs in a large commercial complex, it can spread very quickly and grow into a large fire in a short time, while the shelter of the rack usually decrease the sensitivity of the fire detection system and cause delay. As a result, fire can't be detected and controlled timely. The other reason for quick fire spreading is that the vertical space formed by the atrium and escalators in the complex may help fire and smoke to spread to the whole building.

2.3 Large casualties and property loss

The large commercial complex usually accommodates valuable merchandises and facilities. Once there is a fire, big property loss is inevitable. And what's more fatal is that there are usually large assemblies present. The heavy smoke with CO, CO2, NOx, HCN not only affects the safe and quick evacuation of the people, but also put them in danger. According to the statistics of Japan and UK, the percentage of deaths caused by suffocation in the fire can be as high as 78.9%. As a result of a complicated layout, large assembly of people, long time to evacuate, the large commercial complex is susceptible to fatal fire accidents which usually suffer heavy casualties. For example, on Sept. 30, 1997, a fire occurred in a supermarket on the third floor of a shopping mall in Changchun, Jilin province. It caused 11 deaths and 2 injuries. The burning area reached 4500m2 and most of the commodities inside the supermarket were burnt. The direct property loss was RMB 14,611,000 Yuan.

3 Analysis of difficulties in fire protection design of large commercial complex

Comparing with the ordinary building, the commercial complex is large and usually multi-functional. During the construction, new materials, technologies and structures are employed, which often bring about difficulties in its fire protection design.

3.1 There are no applicable requirements for the fire protection design of the complex in the current national fire code

For the fire protection design of a large commercial complex, the current national standard has covered the following points:

- the building style and the distribution of business operations inside the complex;
- the style of the indoor walking street;
- how to determine the fire load of the complex;
- if the walking street inside the complex can be used as a safe evacuation area? If yes, what kind of conditions should be provided;
- the occupancy density, fire fighting equipment, smoke control pattern as well as other important design parameters;
- the size and separation of the shops along the both sides of the walking street.

3.2 There are limitations in the fire code for the fire designing of the large commercial complex

Here just gives an example to illustrate the limitation. The requirements for the evacuation of the people in "Code for design of shop buildings"JGJ48-88 can't meet the need of the evacuation system of the large commercial complex. Personnel convert quantity in JGJ48-88 is based on the business area and the area of the storage, which is totally unfit for the new layout of a complex with modern ideas and novelties. The evacuation width calculated

according to the method given in JGJ48-88 is usually too big. As a result, more staircases will be required, which not only brings great difficulties in the designing of the evacuation system, but also create enormous waste. At the same time, the layout, structure as well as the aesthetic quality of the complex will be affected too.[68~70] Therefore, it is improper to determine the evacuation width or other parameters according to the calculation method given in the current standard.

3.3 Some of the requirements in the current code can't be implemented easily in the fire protection design of large commercial complex

- Fire compartmentation.

It is required in the current fire code that the fire compartment of the commercial buildings shall not be larger than 5000m2. However, the building area of a large commercial complex is usually as big as hundreds of thousands of square meters. If the fire compartment is divided strictly according to the requirements of the fire code, many many fire compartments, staircases and exits will be provided. The result of this is that the arrangements of the business area will be greatly affected and the function of the complex will be completely limited.

- Fire separation.

"Code for fire protection design of tall buildings" GB 50045-95(2005 edition) requires that if the building area of an underground shopping mall is larger than 20000m2, fire wall shall be used to separate it and there shall be no openings in the fire wall. But in practice, many underground shopping malls with building area larger than 20000m2 haven't been separated by fire walls with no openings. The tall building code further regulates that if it is really difficult to provide a fire wall, then fire roller shutter can be used instead of fire wall. When the fire roller shutter whose temperature rise at the unexposed side is used as the fire resistance rating criteria is used, its fire resistance rating can't be less than 3.00h. When the fire roller shutter whose temperature rise at the unexposed side is not considered, independent close-type sprinkler system shall be installed at the both sides of the shutter and the time for the sprinkler to work continuously shall not be less than 3.00h. In the practice, many owners of the large commercial complexes hope to use transparent glass to replace the separation walls at the both sides of the passageways and those around the atrium, but the glass can't meet the requirements of 3.00h required by the code.

- Safe evacuation.

The typical problem for the fire protection design of large commercial complex is that its travel distance and evacuation width can't meet the requirements of the code.

"Code for design of building fire protection and prevention" GB 50016-2006 requires that the linear distance between any point in the shopping areas inside the Class A and Class B buildings and the nearest exit should not be larger than 30m; when the building is protected completely by sprinkler system, the maximum safe travel distance shall be 37.5m; the end of the staircase on the first floor shall be provided with exit directly leading to outdoor or shall be enlarged. When the building is not more than 4 stories, the exit directly leading to outdoor can be located at the place that is not more than 15m away from the staircase. But in practice, it is not enough for large commercial complex to provide emergency staircases only at the periphery of the building because the complex is usually quite long and deep. Therefore, more staircases shall be provided in the middle. According to the requirements of the fire code, these staircases in the middle part of the building must have exits directly leading to the outdoor, which is completely out of the question.

"Code for fire protection design of tall buildings" GB 50045-95(2005 edition) requires that the linear distance between any point in the shopping areas and the nearest exit should not be larger than 30m. In practice, the emergency staircases of the high-rise commercial buildings are also provided at the periphery of the building. The linear distance between the least favorable point to the nearest staircase is often larger than 30m. But in order to meet the requirement of the tall building code, staircases in the middle of the building must be provided. However, the staircases in the middle of the building can't directly lead to outside.

- Fire fighting.

Both “Code for design of building fire protection and prevention” and “Code for fire protection design of tall buildings” require that where the length of the building along the street is more that 150m or the total length of the building is more than 220m, a well situated fire vehicle access shall be provided to cross the building. For large commercial complex, it is quite difficult to provide fire vehicle access to cut the building apart. Therefore, in practice, many designers propose to use the walking street as the fire vehicle access, but it can’t meet the fire fighting need of the fire vehicles.

4 Current research status at home and abroad

Currently in China, the researches on the fire protection design of large commercial complex mainly focus on the analysis of some fire protection system.

Zhao Hualiang analyzed the commonly used index and parameters of evacuation design. Parameters used for design of evacuation system of large commercial complex such as number of people, evacuation width, travel distance as well as emergency lighting have been discussed.

Aim at the difficulties in designing of the fire partition in commercial construction, Zheng Yanqiu analyzed the general requirements for the design of the sunk plaza, fire compartment, protected evacuation passage and atrium. The application of cesium and kalium fire protection glass and toughened glass protected by water sprinkler as the fire partition was also studied.

Guo Jinjun and Zhao Lijun introduced the difficulties in the designing of water based fire fighting systems as well as the solution.

Guo Xiaolong and Wang Lingjian introduced a method to solve the problem of fire separation of a large commercial complex as well as atrium smoke extraction by separating inner atrium and horizontal sliding skylight.

“Code for fire protection design of large commercial complex in Chongqing” provides a method to calculate the width of exit and series of parameters that are applicable for Chongqing city. In the code, the concept of calculating the width of the exit based on the fire compartment was put forward for the first time. The requirements that the exit can be borrowed or shared by the adjoining fire compartments are provided and the calculation method to calculate this kind of exit is given. For the shopping malls with quite many stories above ground, this local code of Chongqing introduces the concept of “refuge space”, which provides favorable conditions for the emergent evacuation of the people.

Chen Wei introduced his method of providing a safe evacuating passageway on the first floor to lead directly to the outside of the building so as to solve the problem that the staircase in the middle of the building can’t meet the travel distance requirement of the code.

Li Xin and Gu Yu suggested to design a safe evacuating passageway on the first floor to solve the problem that the staircase in the middle of the building can’t meet the travel distance requirement of the code. At the same time, they provided detailed requirements for the designing of the exits, atria, smoke control system and fire fighting system.

Aiming at the problems in the requirement of the fire code-“if the building area of an underground shopping mall is larger than 20000m2, fire wall shall be used to separate it and there shall be no openings in the fire wall”, Kang Dasheng and Wang Jinling suggested to provide a so-called “open fire isolating area” (sunk space) and “closed fire isolating area” . They also suggested to provide an emergency passageway less than 55m long on the first underground floor to directly lead to the outside of the building. For those large space areas like the atrium and indoor walking street, they suggested to install intelligent sprinkler system especially for large space areas.

The above mentioned researches mainly focus on the problems in the design of the commercial buildings. Solutions from the experiences during design, review and construction have been proposed, but they are not complete and thorough. The results can’t be generalized.

Some foreign building and fire codes have some requirements for the fire protection of commercial buildings. For example, building code of Canada, fire code of Singapore, building code of New Zealand and the “Uniform Building Code” of NFPA etc. However, these requirements are mainly applicable to ordinary shops, not the large commercial complexes in China.

5 Conclusion

In order to solve so many practical problems encountered in the fire protection design of the large commercial complex, to evaluate the fire safety performance of this kind of building scientifically, and to define the scientific, reasonable and economic fire safety system, it is necessary to study the key technology of fire protection based on the practical fire loads and occupant density in the large commercial complex in China. Through this research, the related technical requirements of fire protection design were determined, and the scientific, reasonable and economical method of fire protection design was proposed. It is very important to understand the method and to prevent the occurrence of fire so as to safeguard the life safety and reduce property loss.

References

[1]Fire Bureau of MPS.. Anthology of disastrous fire cases of China,2008.

[2]LI Yin-qing. Performance Design for Building Fire Protection. Beijing: Chemical Industry Press.2005.141~171.

[3]LI Yu. Study on Performance-based Fire Protection Design of Large Shopping Centre. *MA thesis of Xi'an University of Architecture & Technology*,2005.

[4]ZOU He. The key technology research for performance-based design of underground commercial building. *Engineering Master Degree Dissertation of Chongqing University*,2007.

[5]LI Xin, GU Yu. Discussion on the problems in the evacuation design of large commercial complex.. *Fire Technology and Products Information,*2007,12,31~33.

[6]Chongqing Construction Committee. DBJ 50-054-2006 Code for fire protection design of large-scale commercial buildings of Chongqing,2006.

[7]HUO Ran, YUAN Hong-yong. Performance-based Fire Protection Design and Analysis.Hefei:Anhui Science & Technology Publishing House, 2003.

[8]ZHAO Wei. Evaluation of performance-based design on giant commercial building.*Fire Science and Technology*, 2009,28(11),817~819.

[9]The Ministry of Public Security of the People's Republic of China. GB50016-2006 Code of Design on Building Fire Protection and Prevention. Beijing: China Planning Press,2006.

[10]The Ministry of Public Security of the People's Republic of China. GB50045-95 Code for fire protection design of tall buildings(2005 Edition).Beijing: China Planning Press,2005.

[11]Civil Air Defence Office of China, The Ministry of Public Security of the People's Republic of China. GB 50098-2009 Code for fire protection design of civil air defense works. Beijing:China Planning Press,2009.

[12]Central-south Architectural Design Institute. Code for Design of Shop Buildings(draft) JGJ 48-88. Beijing:China Architecture & Building Press,1988.

[13]LIN Feng. Studies on the Fire Safe of Large-scale Commercial Buildings. *MA thesis of Xi'an University of Architecture & Technology*,2009.

[14]ZHAO Hua-liang. Discussion on Safe Evacuation from Commercial Buildings.*Fire Technology and Products Information*,2005,2,9~11.

[15]JING Jian-sheng, NI Zhao-peng, ZHUANG Jing-yi. Calculation method of the number of safe egress occupants in commercial building. *Fire Science and Technology*,2003,22(5),351~353.

[16]ZHANG Shu-ping, JING Ya-jie. Research of evacuation crowd in the business hall of large department stores. *Fire Science and Technology*,2004,23(2),133~136.

[17]QI Xiao-xia, PAN Jing. Research of evacuation crowd in the large specialized stores. *Fire Science and Technology*,2005,24(1),60~64.

[18]CHEN Wei. Fire-fighting Design for the Shopping Mall. *Anhui Architecture*, 2008,15(4),29~31.

[19]LI Gen-jing. On the design and management of safe evacuation of large commercial building. *Fire Science and Technology*,2009,8(10),784~787.

[20]YAN Xiao-long,WANG Ling-jian. Fire protection design of large-scale commercial building. *Fire Science and Technology*, 2007.26(5),523~525.

[21]ZHENG Yan-qiu. Analysis of fire protection separate design in commercial construction [J]. Fire Science and Technology,2009,28(1),43~46.

[22]GUO Jin-jun, ZHAO Li-jun. Design difficulties and solutions for water fire-extinguishing system in the mall [J]. Water & Wastewater Engineering,2008,7(34),86~88.

[23]GUO Sheng-you, LIU Mei-mei. Idea and characteristic of code for the fire prevention design of large-scale commercial buildings of Chongqing [J]. Fire Science and Technology, 2007, 26(1), 49~51.

[24]KANG Da-sheng, WANG Jin-ling. The Measures of Large-Scale Shop Fire Prevention Designing [J]. Journal of Chinese People's Armed Police Force Academy,2008,24(10),15~17.

[25]National Research Council of Canada.National Building Code of Canada[S].2005，Volume 1.

[26]Singapore Civil Defence Force.Singapore Fire Code[S].

[27]NFPA. NFPA1 Fire Code 2009 Edition[S],2009.

[28]R.L.P. Custer & B. J. Meacham. Introduction To Performance based Fire Safety. National Fire Protection Association, Quincy, MA, 1997.

[29]SFPE engineering guide to performance–based fire protection:analysis and design of buildings.First Edition,National Fire Protection Association,Society of Fire Protection Engineers,USA,2000.

[30]British Standards Institution. Draft British standard BSDD240 fire safety engineering in building,Part l: Guide to the application office safety engineering Principles,1997.

[31]SFPE engineering guide to performance–based fire protection: analysis and design of buildings. First Edition, National Fire Protection Association, Society of Fire Protection Engineers, USA, 2000.

[32]Building Code of Australia, Australia Building Code Board, October 1996.

[33]Hadjisophocleous G V, Benichou N. Development of performance-based codes, performance criteria and fire safety engineering methods.International Journal on Engineering Performance-based Fire Code, 2000, 2(4), 127~142.